Enhanced Ground Control For ISS Robotics

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Problem Statement

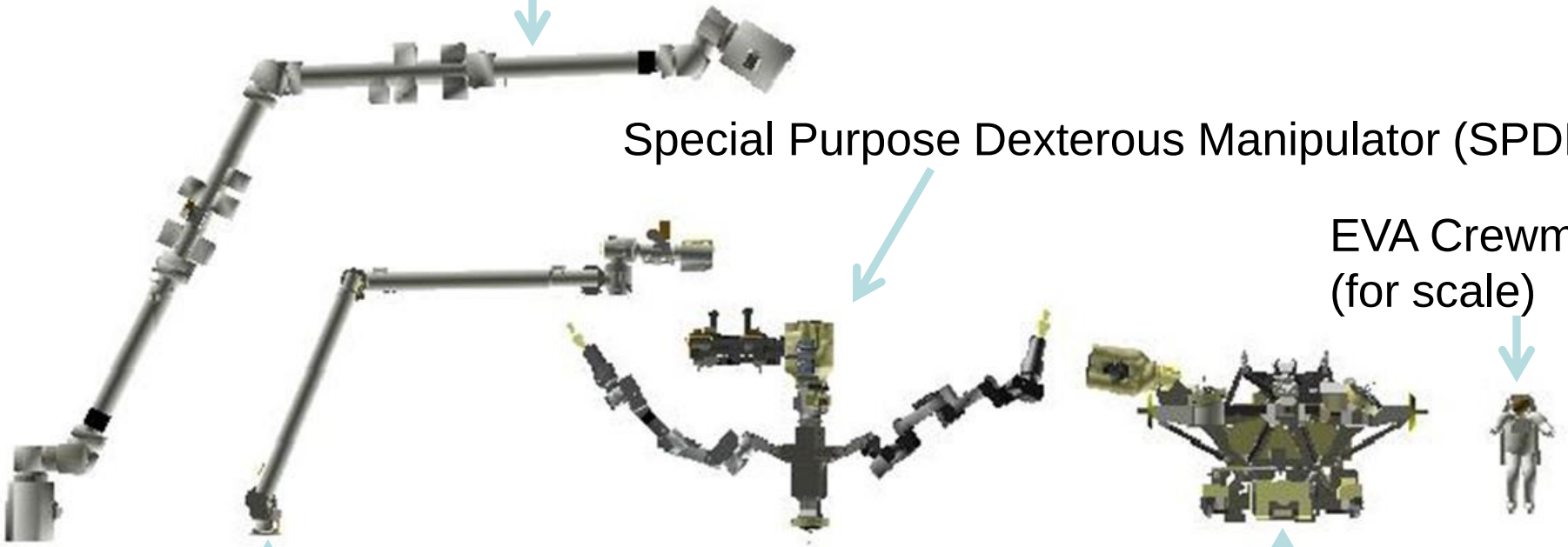
- **The ISS is moving to as much ground control for robotics as possible in order to free up crew time (SPDM ops are 100% GC)**
- **Performing robotic operations on ISS is a time consuming process (1-3 days)**
- **Because planning for robotics operations is a constraint driven process, there are few windows (1-3 days) available**
- **This limitation of available windows is in conflict with our desire and need for an increasing number of robotic operations**

ISS Robotic Systems

Space Station Remote Manipulator System (SSRMS)

Special Purpose Dexterous Manipulator (SPDM)

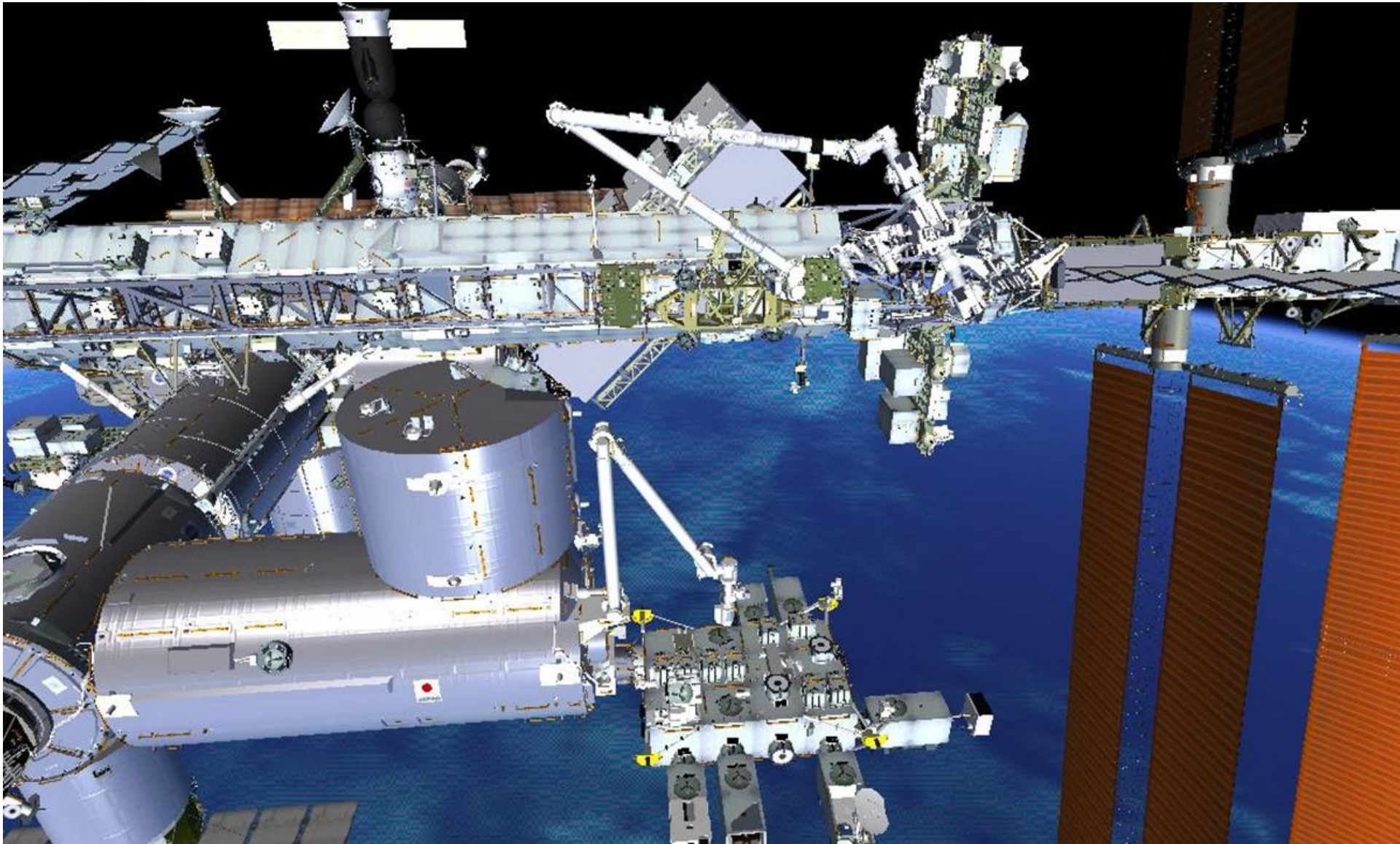
EVA Crewman
(for scale)



JEM Remote Manipulator System (JEM RMS)

Mobile Base System (MBS)
On Mobile Transporter (MT)

ISS Robots



Objective

- **The objective of this effort is to increase the efficiency of ISS ground-controlled robotics operations**

- **Use a phased approach to steadily increase the necessary system infrastructure and increase confidence in the system in a fashion similar to how ground control was implemented**

- **The successful outcome will provide a tremendous increase in robotics utilization for the life of ISS as well as provide the blueprint (and validation) for future exploration missions utilizing remote robotic operations**

Premise

- **The MSS is existing hardware and software that is not easy to modify (both from a cost and technical perspective)**
- **Intelligent ground control aids can be developed to improve and increase efficiencies for the GC operator**
- **The primary sensor that is available to provide information and help close the loop is video**

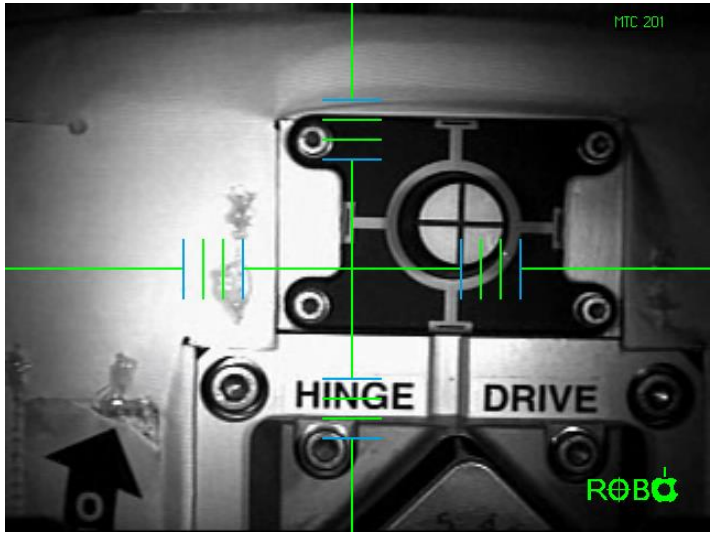
Background

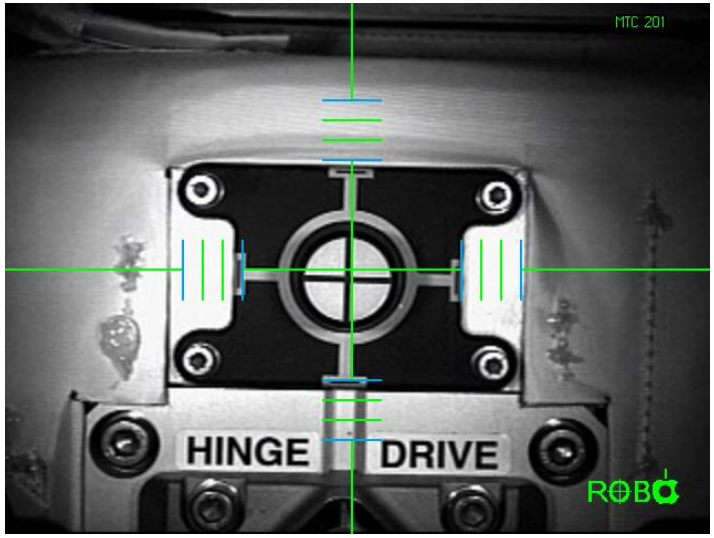
- **Joint effort between DX2 and ER3/4 to develop a machine vision based application to assist with alignment during MSS Ground Control operations.**
  - **Initially focused on SPDM grasp fixture operations**
    - Current technique for alignment is operator interpretation of misalignment using OTCM camera view with ground overlay system.
    - Operator issues commands to remove misalignment by flying the overlay crosshair to the center of the target.
    - Machine vision alignment will reduce time required for alignment and potentially eliminate missed grasps.
  - **Expandable to ORU R&R/Payload install alignment**

Grasp Operation Comparison

Manual alignment	Machine Vision assisted
Scripted OCAS mnvrs to 8cm axial separation	Scripted OCAS mnvrs to 16cm axial separation
Manual alignment using GC Overlay system and Soft HC application	Alignment and direct mnvr into grasp envelope performed by Machine Vision. (Brakes On not required) Grasp commanded automatically.
Manual mnvr into grasp envelope. (Brakes On required when operator determines within grasp envelope)	
Brakes off and back into OCAS mode.	
Grasp commanded by operator.	

Target Alignment Challenge

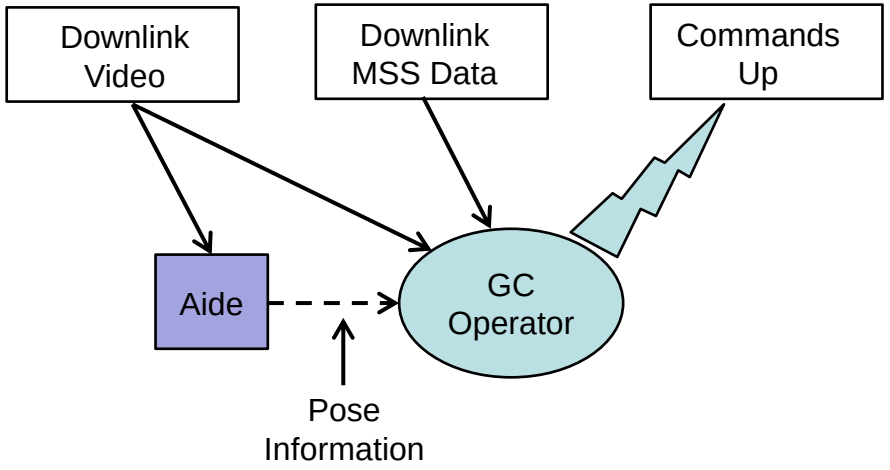




- **Target based operation**
  - **Maneuver the OTCM to line up the OTCM camera/overlay with the grasp fixture target**

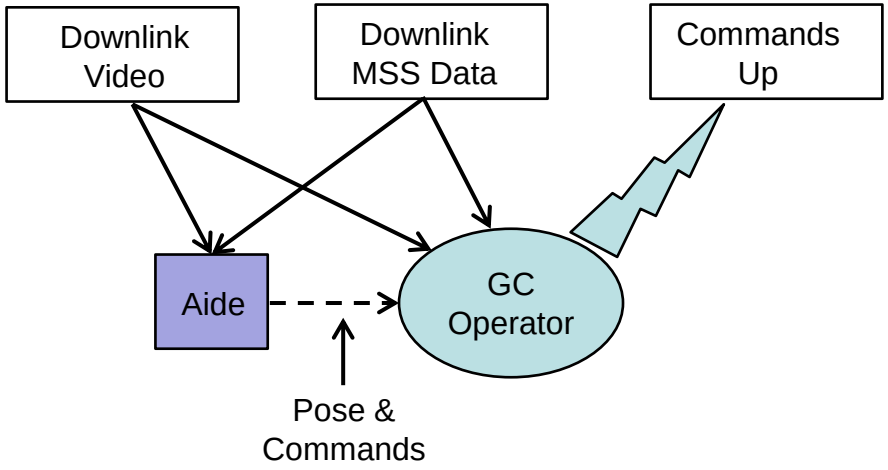
Development Phases

- **Phase 1 – Initial Aide Identification and Development**
  - **Joint development effort with ER and DX**
  - **Aide would provide additional/enhanced information to the operator, like digital pose estimation based on Natural Feature Image Recognition (NFIR)**
    - **Starting with one of the most time-consuming and most frequent ground operations – SPDM grasp of hardware fixtures**
  - **Initial implementation would be a standalone box, i.e. something that can be taken to a simulator or MCC and just plug a video feed into it.**



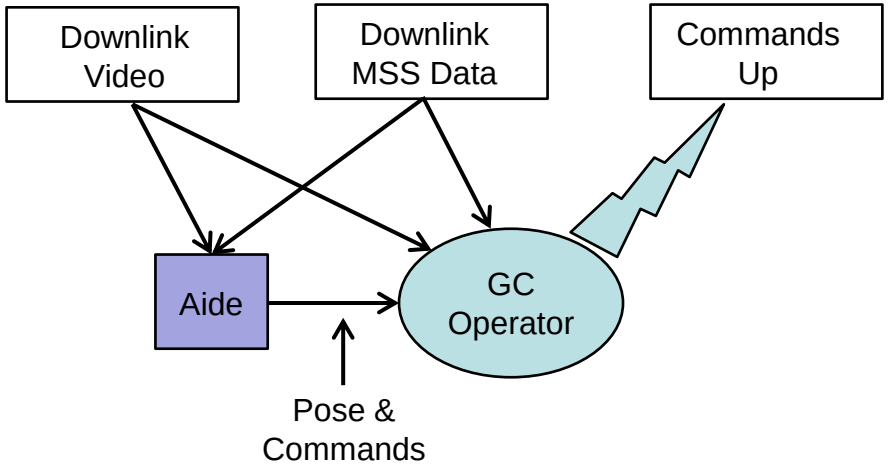
Development Phases (cont.)

- **Phase 2 – Increased Aide Functionality**
  - **Aide could suggest MSS commands or perhaps even go so far as generate the commands, but not send them.**
  - **Begin fusing data from various camera views and MSS system data (i.e., control modes, joint position, etc.)**
  - **Ground retains full control over what commands get sent onboard**



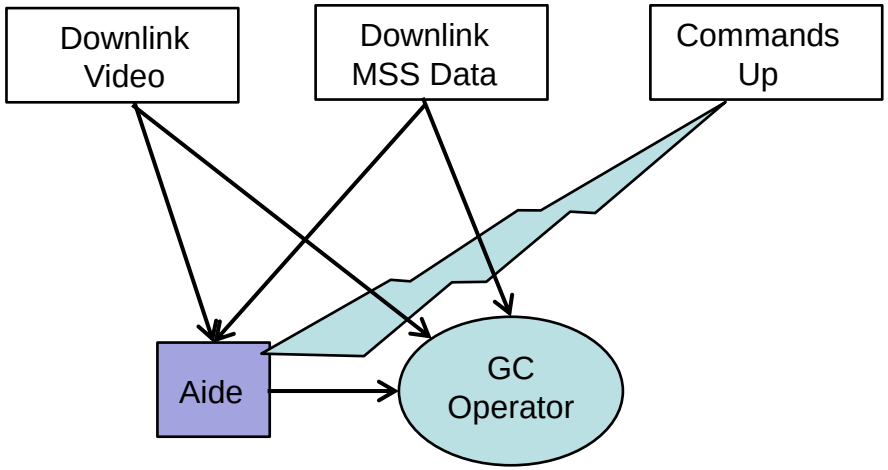
Development Phases (cont.)

- **Phase 3 – Limited Autonomy**
  - **Aide generates and sends a subset of MSS commands perhaps limited to only non-motion commands or motion commands limited by distance to structure and TDRS coverage**
  - **More mature and increased data fusion capability**
  - **Ground still does "close quarters" commanding, and would still have the responsibility to monitor and be prepared to safe the system if necessary**



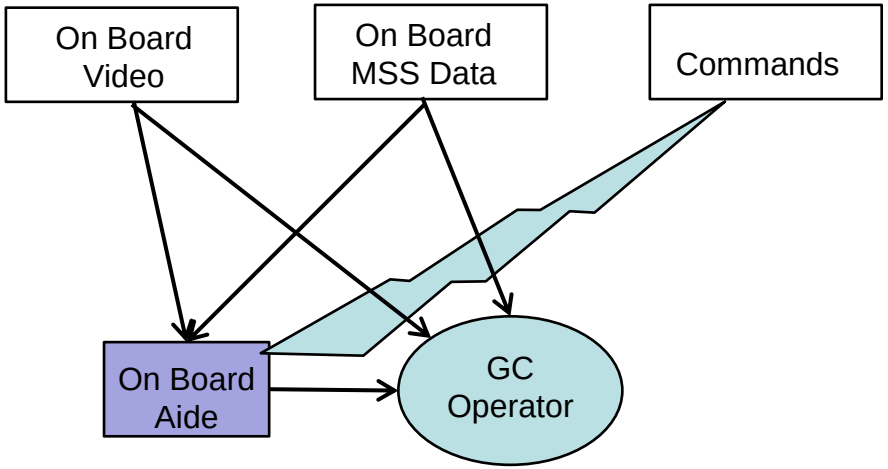
Development Phases (cont.)

- **Phase 4 – Full Autonomy**
  - **Aide generates and sends all MSS commands regardless of motion distance and operational complexity**
    - **No motion during Ku-band or S-band LOS**
  - **Full maturity and intelligence of data fusion capability**
  - **Ground would still monitor and would still be able to safe the system if necessary**



Development Phases (cont.)

- **Phase 5 – Full Autonomy (On-Board ISS)**
  - **Aide generates and sends all MSS commands regardless of TDRS coverage**
    - **Stand-alone software would be needed onboard to continue during LOS periods (may require sub-phases to get to full implementation)**
    - **No changes to MSS software**
  - **Ground would still monitor when not LOS and would still be able to safe the system if necessary**

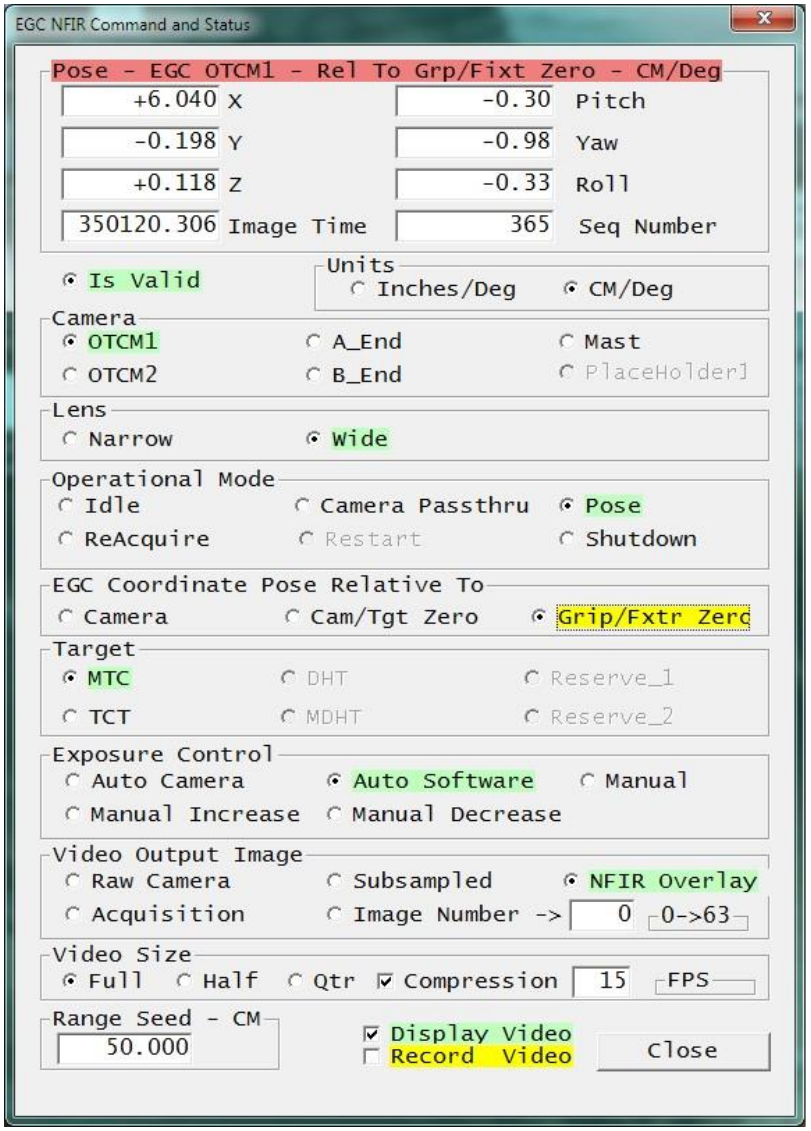


Current Status

- **ER and MOD awarded funds for Phase 1 through the JSC IR&D for proof-of-concept development**

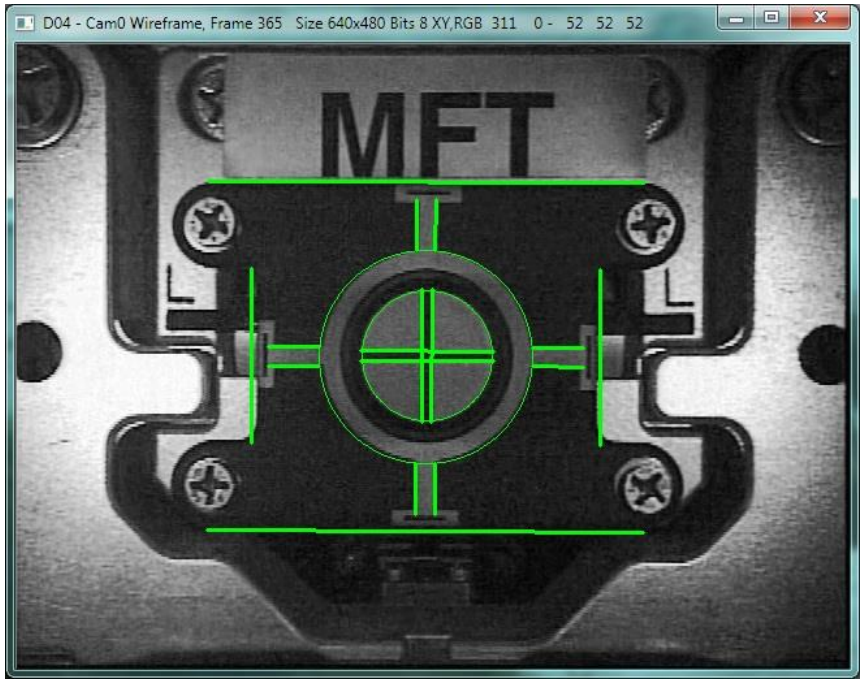
- **ER developed NFIR capability based around MTC target and grasp operation using video from recent grasp operations**
  - **Initial results showed that the concept works as desired and that continued development is worthwhile**
  - **A real-time test in the MCC was done in June had very encouraging results**

Enhanced Ground Control Demo



User interface showing alignment positional error

Green overlay provides visual feedback of tracking



Conclusion

- **The proof of concept of Phase 1 has been completed successfully.**
- **Pursuing the subsequent Phases will expand the operational capability and the autonomy by which operations can be executed.**
- **By utilizing MSS and ISS data, as well as the ISS video assets, full autonomy is expected to be achieved.**
- **With this autonomous capability, operations such as full video inspections of the ISS, can be successfully accomplished in a time and resource constrained environment.**